REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE (*MM-DD-YY*)	2. REPORT TYPE	3. DATES COVERED (*From - To*)
05/27/08	Quarterly Report	2/27/08 to 5/27/08

4. TITLE AND SUBTITLE

5a. CONTRACT NUMBER N00014-05-C-0294

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Matthew Welborn

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Signal Innovations Group
1009 Slater Road
Durham, NC 27713

8. PERFORMING ORGANIZATION REPORT NUMBER

SIG.ONR.OPT3.Q2

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research
ONR 251: Wade Wargo (703) 696-2574
875 N. Randolph Street Suite 1425
Arlington, VA 22203-1995

10. SPONSORING/MONITORING AGENCY ACRONYM(S)

11. SPONSORING/MONITORING AGENCY REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT A

13. SUPPLEMENTARY NOTES

14. ABSTRACT

During this reporting period, we have completed the integration of our robust detection & tracking engine with the asymmetric threat behavior analysis capabilities that we have developed under this C2CS effort. We have implemented a software application that can process real-time or archived color video data to extract objects tracks and features and to identify in real-time any objects that exhibit anomalous behavior characteristics. The SIG team attended the PI Gathering at ONR in May 2008 and presented our current results as well as providing a demonstration of the integrated software behavior detection application. In recent months, we have also made significant progress in extending our initial behavior analysis work to include long-term track information in addition to the instantaneous object positions and trajectories used in our initial work.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT:	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON (Monitor)
Unclassified	Unclassified	Unclassified			Dr Matthew Welborn **19b. TELEPHONE NUMBER** (*Include Area Code*) (919) 794-3322

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18

1 Summary

The purpose of this program is to address the development of algorithms for adaptive processing of multi-sensor data, employing feedback to optimize the linkage between observed data and sensor control. The envisioned multi-modal adaptive system is applicable for intelligence, surveillance, and reconnaissance (ISR) in general environments, addressing base and port security, as well as urban and suburban sensing during wartime and peace-keeping operations. Of significant importance for current and anticipated DoD activities, the ISR system is designed to detect asymmetric threats, with the goal of recognizing unusual behavior or activities. Technologies and systems developed under this effort will be designed for semi-automated scene awareness, with the objective of recognizing behavior that appears atypical (e.g. atypical object motion, and dynamic characteristics of people and vehicles). Leveraging our previously developed technology, SIG is developing second-generation methods to adaptively learn the statistics of dynamic object behavior in video, while focusing on defining system requirements for sensor deployment by using field data (vs. highly controlled indoor data). SIG is also working closely with its subcontractor, Lockheed Martin, to integrate additional technologies, such as object classification and recognition, to provide a more robust and discriminative system. Additionally, SIG is cooperating with the Navy's China Lake facility to collect representative data for a deployed system, and to specify requirements and features necessary of such a system. Finally, SIG is coordinating with Integrian on prototype development schedules and product integration requirements, and defining a joint marketing and commercialization strategy for such products.

SIG is aggressively pursing follow-on funding and technology transition opportunities for persistent surveillance applications. In particular, under related IRAD efforts, we are working to address current shortfalls and develop new methods for activity recognition of vehicles and dismounts in persistent airborne EO/IR video imagery. An efficient framework is under development for joint classification and target tracking (JCT). The joint posterior density over target poses (e.g. position, velocity, heading) and target type is recursively estimated via a Bayesian formulation. It is assumed that appearance measurements provide information indicative of target class and kinematic measurements for indirect measure of target pose. An importance sampling approach is used to efficiently incorporate both types of measurements in refining estimation of the joint distribution. The methods are presented in the context of providing real-time analytic metadata to reduce data transmission requirements in support of persistent video-based surveillance. Included in this metadata are the joint-posterior distributions for target tracks and class which are utilized by an active learning cueing management framework to optimally task the appropriate sensor modality to cued regions of interest. Moreover, this active learning approach also **facilitates analyst cueing to help resolve track ambiguities in complex scenes.** We intend to leverage SIG's active learning with analyst cueing under future efforts with ONR and other DoD agencies. Obtaining long-term accurate target tracks is a key requirement for activity modeling. We propose adapting methods for activity manifold modeling, such that the posterior distributions of vehicle tracks themselves may be ultimately transformed into space-time probability manifolds. Such representations will enable further application of the active learning

framework for semi-automated activity recognition with limited analyst cueing for anomaly and threat notification.

2 Recent Technical Developments

During this reporting period, we have completed the integration of our robust detection & tracking engine with the asymmetric threat behavior analysis capabilities that we have developed under this C2CS effort. We have implemented a software application that can process real-time or archived color video data to extract objects tracks and features and to identify in real-time any objects that exhibit anomalous behavior characteristics. The SIG team attended the PI Gathering at ONR in May 2008 and presented our current results as well as providing a demonstration of the integrated software behavior detection application. In recent months, we have also made significant progress in extending our initial behavior analysis work to include long-term track information in addition to the instantaneous object positions and trajectories used in our initial work.

2.1 Full integration of tracking engine and anomalous behavior Detection

Over the course of the last few months, SIG has focused its attention on the integration of or behavior analysis algorithms with our real-time object detection and tracking engine to create a Color video ISR system that detects unusual behavior or activities. This system provides real-time operation and supports detection in cluttered environments. At the same time, it can help to deal with situations where there is limited bandwidth to analysts through the use of intelligent compression.

The core engine of this application is the flexible multi-hypothesis tracking. A screen capture is shown of this application in Figure 1. This application supports operation with either live or archived color video data and allows detection and tracking of objects as small as 4 pixels in the target domain. The system can track through total occlusions and can reacquire after as much as two seconds of complete occlusion. This systems demonstrates repeatable tracking accuracy and is robust to occlusions, lighting, and inclement weather. It provides 98.7% data association accuracy with occlusions under testing and was demonstrated on a 0.052/object-minute divergence rate where tracked objects would diverge during occlusion.

This system is an efficient real-time implementation and operates at 15 fps on real-time streaming color video. The system operates even faster on archived video – when not limited by the real-time camera constraint and can operate in excess of 20 fps on a single processor. The system also enables intelligent video compression as it identifies all objects of interest in the foreground. When tracking distributions are employed to allocate data bits, the system provides as much as 39x raw data compression ratio in the target domain using simple compression. Performance as high as 110x encoded data compression ratios possible using more sophisticated compression approaches.

This application was demonstrated at the PI gathering that was held in Arlington on May 12-14, 2008.

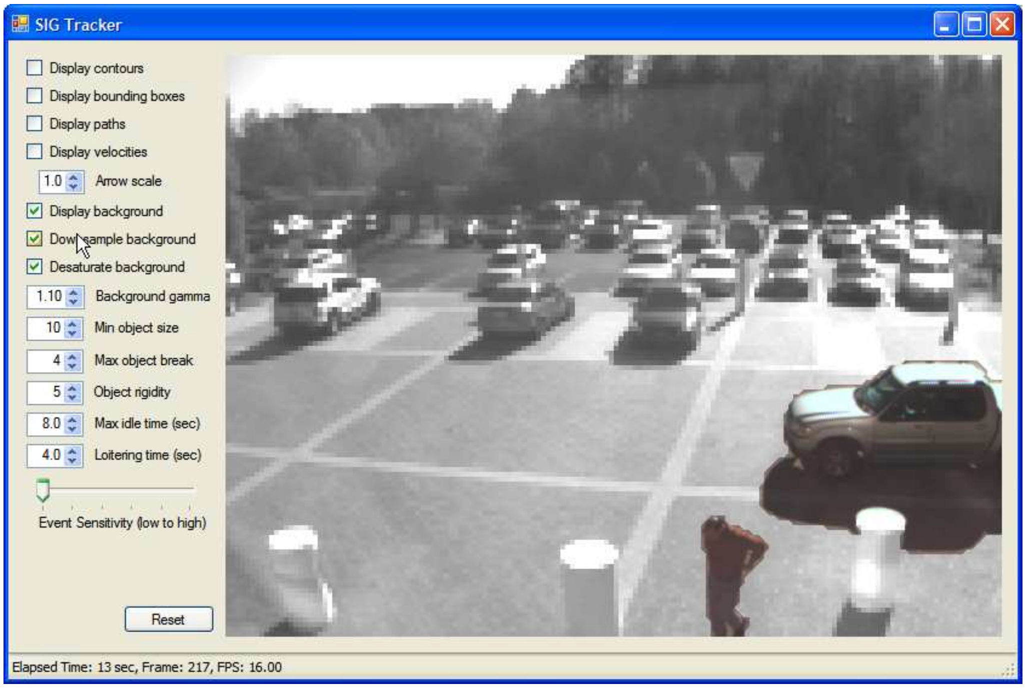

Figure 1: Screen shot of the integrated tracking and anomalous behavior detection application.

2.2 Full track behavior analysis

Our initial behavior modeling was based on instantaneous position and velocity only. This approach characterized behavior in terms of position and velocity and then compared this to past behaviors. The approached used the ***joint probability*** for improved discrimination. Because most unusual actions are suspicious, this approach was able to capture desired anomalous activities such as trespassing, speeding, loitering, and flow control violations. This approach provided a generalized solution that avoided the pitfalls of rule-based systems since the behavior distributions were learned from the scene directly. During testing, this approach demonstrated correct detection of ***all*** anomalous activity in scripted video test sequences within several frames and also detected unscripted objects with anomalous behavior.

During the recent performance period, our modeling efforts are being extended to full motion trajectories. This new approach allows us to characterize behavior in terms of entire track history provided by object tracking engine. For each object, the trajectory is parameterized by arc-length to provide invariance to time sampling. This approach is a learning based strategy where we focus on conditional probabilities of behavior P(Y |X), rather than full joint P(X,Y) (where Y are the behaviors and X are the observes object states). We use boosting and logistic regression (specifically, the LogitBoost algorithm) for training and object behavior classification. The approach was tested on outdoor video surveillance sequences collected at China Lake facility and results are shown in Figure 2.

The initial results were based on an approach that used only object trajectory – subsequent improvements will incorporate appearance of objects as well – and our goal is >95% classification accuracy. Figure 3 also shows a typical video frame from the testing data that shows a typical object with an indication of different potential trajectories. Additional work will also incorporate active learning and additional behaviors.

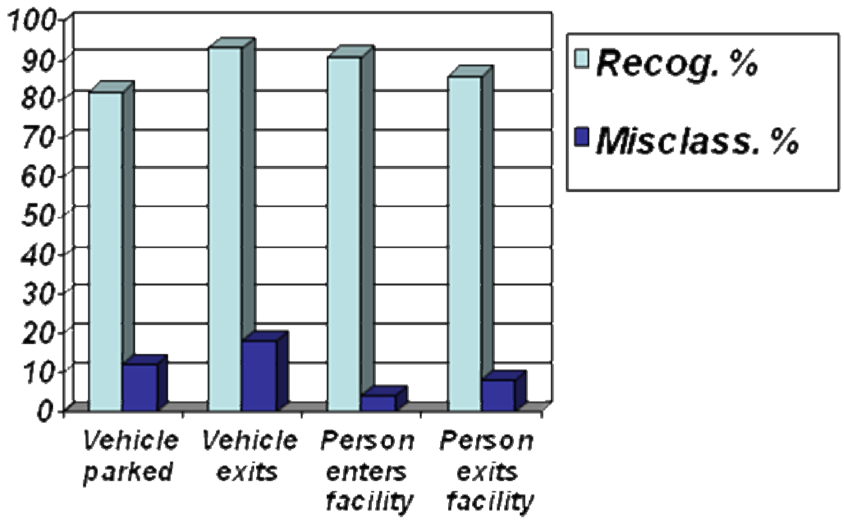

Figure 2: testing results from the full-trajectory behavior analysis on the China Lake data set.

Figure 3: Typical video from form the China Lake data set with indications of conditional object trajectories.

2.3 Technology transition to Persistent Surveillance Applications

We have begun transition of the technology developed under this C2CS effort to multiple other funded research efforts. The ONR-funded SIG C2CS effort has transitioned into funded programs in the applications of Army Persistent Surveillance (Constant Hawk future IR capability – JIEDDO funded), Air Force persistent surveillance (funded by AFRL), and airborne IED detection (funded by NVESD). The technology transitions total $450k per year non-ONR transition funding. For the persistent surveillance applications, the technology will be used to support real-time (or forensic) image and video analysis using the C2CS-developed modeling and Bayesian tracking technology. In this application, analysts will provide feedback to algorithms to resolve tracking and classification ambiguities. An integrated system will cue analysts to regions of ambiguity in algorithm inferences, and any cued regions will be prioritized according to relative information gain. In addition, there is the potential for transition of the intelligent video compression technology that allocates full resolution to critical scene data and compresses background imagery for context. The Army effort will apply this C2CS technology (tracking, behavior analysis and active learning) to Army UAV data sets and the Air Force effort will apply this C2CS technology to the CLIF data set (funded through AFRL).

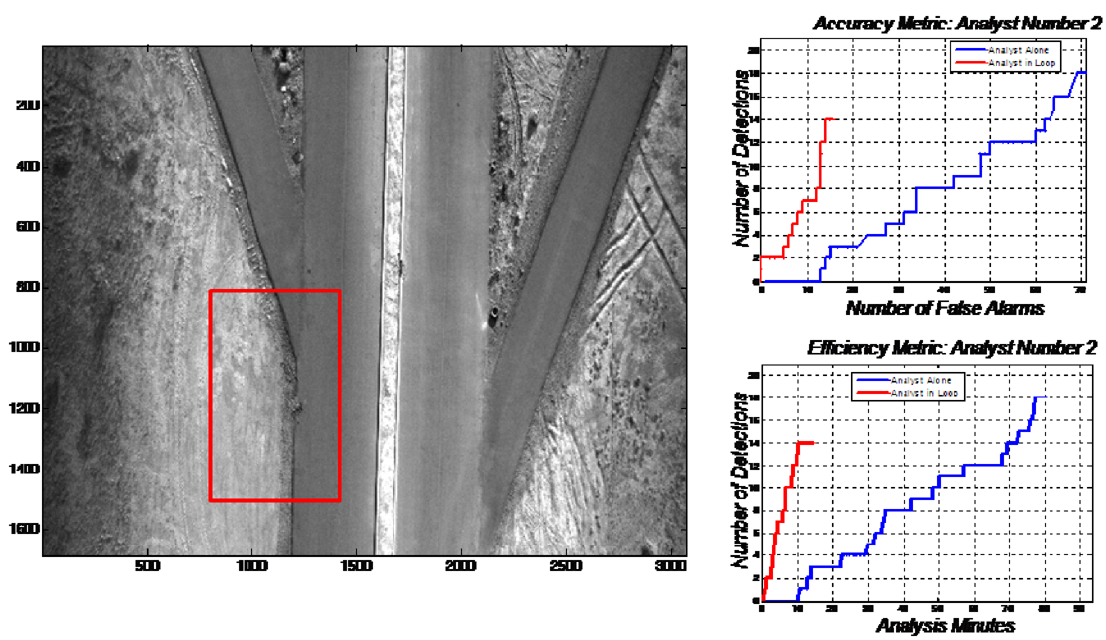

Figure 4: Typical image from the IED target data based along with resulting plots showing improvements in both analyst accuracy (fewer false alarms during analysis) as well as improved efficiency (4-6 time s faster analysis).

The Army NVESD airborne IED detection application will use active learning and video processing to real-time streaming video imagery for target detection. The work will involve the development & testing on borne IR data sets funded through NVESD. Initial results have demonstrated the effectiveness of active learning for improving analyst performance and efficiency. A typical image is shown in Figure 4 where a region of interest has been identified for analyst labeling, and specific results are shown for this data set indicating improvements in analyst accuracy and efficiency. We will report the specific details of these technology transitions separately using the Transition report form that has been provided by ONR to SIG.

3 Future Directions

During the next reporting period, we will continue work on using the concepts of compressive sensing to address some of the fundamental challenges regarding the detection of asymmetric threats. In particular, these concepts can be used to optimize a system to extract the most possible information about possible targets and their behavior under the constraints of system processing and data bandwidth constraints. We will continue the work on transition of the C2CS technology for airborne persistent surveillance applications, as well as for integration with systems that use analyst-in-the-loop technology for analyst cueing to provide more robust tracking and behavior analysis in scenarios where difficult conditions such as poor resolution, environment or light conditions lead to tracking or data association ambiguities. In addition to this near-term work, we are continuing to work toward transitioning the research to other funded research efforts in addition to those identified above.